The Scope of Ergonomics Research and Applications

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Ergonomics is a multidisciplinary field that has applications in a very large number of areas. Definitions of ergonomics differ, and have varied over time, but a current definition that seems to fit most Human Factors & Ergonomics (HFE) practitioners' practical usage is "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance."(IEA). While applications of ergonomics may seem more evident than research as one can see the end product, it follows from the definition that, as a primarily empirical discipline, wherever applications of ergonomics are apparent, they will likely be the result of prior research. There are also many examples of research that do not immediately or directly translate into practical use, and so may exist on their own. This essay attempts to provide an overview of the extent of the applications and research in the ergonomics field.

Research in ergonomics can take a number of related but distinct forms, many of which can be further subdivided into more specific research types. Data collected can broadly be divided into quantitative (numerical) and qualitative (descriptive) types, although studies will often collect a combination of the two. Explicitly quantitative, experimental designs are used to determine causality between two variables. This is particularly useful for relatively simple research questions, such as comparing which fonts are most legible (under a precise operationalisation of the term) (Garvey *et al.*, 2001). Observational/descriptive studies involve researchers recording qualitative data about participants in a setting that could be artificial (typically easier to achieve high internal validity) or naturalistic (greater likelihood of higher ecological validity). To achieve the highest ecological validity possible – looking at "real behaviours" (Gobo, 2008: 46) – researchers may carry out ethnographic studies, which involve observing participants (commonly workers) as they behave normally in the setting of interest. This is then extensively written up and theme-matched, which is a time consuming procedure, but it can yield very rich results. Due to the large amount of time taken, few people can be studied, meaning that statistically abnormal people may produce wildly unrepresentative results.
Evidently, different research types have characteristic strengths and weaknesses, so often multiple types are used together, in an approach called triangulation (Wilson and Corlett, 2005: 22). Creating new variations of research methodologies to study ergonomics is one of its applications, blurring their distinction. For a more comprehensive review of research methods, see Wilson and Corlett (2005: 15-27).

The most well-known application of ergonomics is its physical component, particularly as a part of product design, making sure that products fit their users in a comfortable and non-damaging way. The background research used here is anthropometric data showing the range of human measurements, and their variations in different populations (varying by age, sex, ethnicity etc). A commonly cited collection of data is that by Pheasant and Haslegrave (2005). This data has been collated and digitised in a number of 3D CAD programs (*e.g.* Sengupta and Das (1997), Seidl (1997)), so that designers can virtually test their products against the range of sizes of their customers. Product design that includes an ergonomics approach will also commonly include user trials and interviews (Wilson and Corlett, 2005: 187-90, 301). Products span the gamut of users and uses, including in sports, medical, military and industrial applications. Anthropometrics, together with the studies of physiology and biomechanics, has the potential to improve products from the mundane – the affordances and constraints of door handles are discussed by Norman (2002: 10, 87-88, 91); to the erotic – sex toys are inextricably tied to an understanding of human shape and proportion (Simms and Bust, 2013); to the livelihood-essential – a number of tools used daily by agricultural workers in less developed countries were improved, including the “plough, sickle, shovel, spade and hat” (Sen, 1979, Sen and Bhattacharyya, 1976, Sen and Pradhan, 1978, Sen and Mazumdar, 1978, cited in Sen, 1984: 1025).

The scope of ergonomics research has arguably expanded over recent years to include the emotional impact that a product or system has on its users. Arguments proposed by Nagamachi (1995), Norman (2004) and Jordan (1998) call for ergonomists to concern themselves with the pleasure/displeasure that products can incite. The aspects that have an effect include: “features, usability, aesthetics, performance and reliability” (Jordan, 1998: 25). This vein is continued by Liu (2003), who suggests that along with the traditional HFE dimensions – "arousing quality... information processing demands... psychosomatic soundness" (Liu, 2003: 1274), aesthetics and ethics require attention. ‘Aesthetics’ is used to include a “whole range of aesthetic notions such as the sublime, the beautiful… humorous... ‘cool’... ugly... tragic (Honderich, 1995, Devereaux, 1997, cited in Liu, 2003: 1277), not merely the beautiful. The authors justify their arguments such that research into aesthetics, and the application thereof, come under the scope of ergonomics as defined above: emotional effects can be scientifically studied and come under “well-being” to be optimised.

Design for special interest groups such as the elderly and the disabled is also part of the application of ergonomics. The research of the capabilities of these groups has led to a push towards inclusive design (designs that cater to a wide range of abilities) as well as specialist designs for products and systems of which the general public typically has no need.

There is a large quantity of research that looks at the general abilities/capacities, physical limitations and psychological fallibilities that people as a whole tend to exhibit. The central components of cognitive psychology (memory, attention, perception, decision-making, problem-solving and language) are all relevant here, and much of the research on these has had significant implications on design and organisation. The study of perception and attention has greatly affected the laws and guidelines around car safety, making illegal or explicitly inadvisable not to do those things that exceed our limits, but of which we may not be aware before they cause an accident (Strayer *et al.*, 2003)(*Road Traffic*, 2003). More positively, similar study was a primary part of the design of the nationwide UK police car livery (which was later expanded to all of the UK emergency services), with a focus on conspicuity and recognisability (Harrison, 2004). An example of a psychological fallibility that ergonomists have partially managed to overcome in certain areas is the tendency to commit the post-completion error – after completing the intended objective of a sequence of actions, further actions to finish off the sequence are ignored and forgotten about. This was an issue with ATMs: the objective is to retrieve money; after inserting their credit/debit card, navigating the menus and completing this objective, the card was sometimes forgotten about and the customer would walk away leaving their card in the machine. Only a simple change was needed to fix the issue: changing the order so that a customer will not receive their money until they have removed their card, after which they will still be focusing on the intention of retrieving money, and so leave nothing in the machine (Curzon and Blandford, 2000). Human error in general has been widely researched, as it has a broad application in numerous workplaces. In many of these, 'human error' (often actually deficient design) could lead to injury or loss of life. There has been differentiation between different sorts of error, *e.g.* omission vs commission (not performing an action vs performing one incorrectly) and slips vs misconceptions (unintentional mistakes vs intentional actions that were not known to be wrong), which need to be approached differently when trying to reduce them. There have also been attempts to model systemic errors, such as the swiss cheese model: incidents occur when multiple errors, both latent and active, line up (Reason, 1990).

The physical limits of people have also been of great interest to the ergonomics community. Manual Materials Handling (MMH) in particular has come under scrutiny, as the movement of often heavy objects is part of many workplaces. The application of the large quantity of research is that formulae have been developed through three ergonomics approaches (biomechanical, physiological and psychophysical) to determine accepted weights that workers may lift and/or carry depending on a number of factors including frequency, number of lifters and lift height (Sanders and McCormick, 1993). These are codified in NIOSH guidelines (Waters *et al.*, 1994). Lifting limits in the workplace have great precedence in construction sites, which also have a number of other biomechanical dangers. The recent advances in overcoming these have been published in papers such as that by Koningsveld and Van Der Molen (1997). Limits discovered and quantified by research provide constraints for designers of everything from products to systems.

Ergonomics is involved not only in biomechanical aspects of workplaces, but also in managerial and work organisation. Hendrick (1991) discussed a set of appropriate terminology for describing the various dimensions of an organisation, the interplay between them and recommendations for the macroergonomics approach both for performance and wellbeing. Organisation of tasks was also tackled by early ergonomists. Barnes (1958) and Gilbreth (1911) carried out motion studies to break down the movements performed during an action, with the intention of then optimising the performance. For slightly larger scale performance optimisation, they also invented an icon

language for classifying the actions that workers would perform – "therbligs" (Salvendy, 2004). Later research in a similar vein, along with anthropometric data, has led to ergonomic guidelines for workstation UI (Das and Sengupta, 1996). Applications of this sort tend to improve the performance of the worker as well as their satisfaction and well-being (Vink *et al.*, 2006).
There has been some significant ergonomics research in the field of information processing. As computers became more prevalent, such that they are now a part of most people's work and everyday life, ergonomists focused on researching Human-Computer Interaction (HCI). With previous data on human cognitive abilities as a background, the more contemporary research gave rise to guidelines with respect to information processing (*e.g.* Nielsen, 1995). The topic of information processing also covers earlier research such as that done on the intelligibility of speech (Bilger *et al.*, 1955) which has a relevant application for everyone who communicates with others verbally, *i.e.* almost everybody. It is of particular importance to public speakers. There were a number of factors, all of which could be implemented with practice and/or intention, including mean syllable emphasis and duration.

Many of the systemic safety improvements in dangerous job areas have come as a result of ergonomists studying disasters in those areas, investigating the causes at the blunt and sharp ends of the incident. One significant such event was the Piper Alpha oil rig disaster, which involved numerous failures: improper conversion of the plant from processing oil to processing natural gas; alerting pressure gauges ignored due to their known frequent malfunctions; poor layout of the buildings/offices leading to an inability to effectively call mayday after the initial explosion and fire breakout; and unwillingness of the company to stop pumping fuel from a nearby rig, which caused a second, larger explosion. The analysis of the incident by ergonomists led to 106 new regulations for oil rigs, and there have since been no similar incidents (Singh *et al.*, 2010).

To conclude, the scope of ergonomics is very large for both research and application thereof. Ergonomics has applications in all levels from the macroscopic (creating standards and affecting laws) to the microscopic (button positions on a control panel) and across a variety of purposes (sports, medical, military, consumer products, workplaces, industry, public utilities…). Similarly, the research ranges from the simple (determining the best order of ATM actions) to the very complex (modelling the numerous factors in construction accidents (Haslam *et al.*, 2005)) and uses a number of fields (biology, cognitive psychology, gerontology, medicine, engineering…). Indeed wherever there are people interacting with each other, any objects or their environment, there is scope for ergonomics to have a role.

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